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RA Gaikwad
M. Sc. (Agri. Student)
Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

SS Shinde
Assistant Professor, Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

AA Dalvi
M. Sc. (Agri. Student)
Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Corresponding Author:
RA Gaikwad
M. Sc. (Agri. Student)
Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Effect of foliar application of plant growth regulators on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench)

RA Gaikwad, SS Shinde and AA Dalvi

Abstract
The field experiment was conducted on field of Department of Agricultural Botany, College of Agriculture Parbhani, during *kharif* season of 2019, to study the effect of foliar application of plant growth regulators on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench). The experiment was laid out in randomized block design with ten treatments and three replications. The treatments consisted of three growth regulators *viz.*, gibberellic acid (25, 50, 50 ppm), naphthalene acetic acid (25, 50, 75 ppm) and indole-3-butyric acid (25, 50, 75 ppm). Results revealed that the application of plant growth regulators significantly increased morpho-physiological traits *viz.*, plant height, number of branches per plant, number of leaves per plant, number of flowers per plant, days to 50% flowering as compared to control. Application of growth regulators increased all the yield attributing parameters *viz.*, fresh fruit weight, number of fruits per plant and fruit yield which increased significantly due to plant growth regulators. The fruit yield improved with the foliar application of gibberellic acid (GA_3) followed by naphthalene acetic acid (NAA), indole-3-butyric acid (IBA) compared to control.

Keywords: GA_3, growth, IBA, NAA, Okra, plant growth regulators, yield

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench] is a herbaceous annual plant which belongs to family Malvaceae, growing in tropical and subtropical parts of the world. It is also grown throughout the year for its tender green fruits. India is the largest producer of okra. Besides being a vegetable, it also has medicinal and industrial importance. It requires long and warm growing season and is susceptible to frost. The optimum day temperature for its well growth is between 25 ˚C to 40 ˚C and that of night is over 22 ˚C.
Okra contains fibre which is suitable for the manufacture of paper and cardboard (Aloni, 1990) [1]. This fibre keeps sugar levels in blood under control, providing sugar quantity acceptable for the bowels. Mucilage found in okra is responsible for washing away toxic substances and bad cholesterol, which loads the liver.
The application of plant growth regulators are known as the most effective treatment used now a days in agriculture. Production of horticulture crops and their productivity were increased by application of different growth regulators (Jafarullah *et al.*, 2007) [6].
There are six recognized categories of natural plant growth hormones. They are Auxins, Gibberellins, Cytokinins, Ethylene, Abscisic acid and Brassinosteroids. They play important role in growth and development of plant. In the present study we are concerned with plant growth regulators *i.e.* GA_3, IBA and NAA. Auxin IBA plays important role in cell elongation and encourage cell division. Gibberellins were named after a genus of fungi that cause "foolish seedling" disease (Yabuta, 1935) [15]. There are more than 100 distinct gibberellins produced primarily in roots and young leaves but GA_3 or gibberellic acid is the most popular available form. GA_3 has many effects on plant growth such as enhance stem and internodes elongation, produce seed germination, enzyme production during germination, fruit setting and growth (Davies *et al.*, 1995) [5]. Naphthalene acetic acid (NAA) is a synthetic auxin. NAA stimulates cell elongation, used for flowering and so on. The effect of NAA on plant growth is greatly dependent on the time of admission and concentration. Keeping these facts in view the present investigation was carried out to study the Effect of foliar application of plant growth regulators on growth and yield of okra.

Material and Method
The present experiment was conducted at Research Farm of Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

The details of the material used and methods adopted during the present investigation presented in this chapter. The investigation was carried out at Experimental Farm, Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The field selected for experiment is uniform with typical medium soil having medium fertility and fairly good drainage. Agro climatically Parbhani is situated at latitude, longitude and altitude of 19^0 16' N, 76^0 47'E and 409 m, respectively. Parbhani district falls under Central Maharashtra Plateau agro-climatic zone (MH-7) in Maharashtra. The district receives annual rainfall of 916.0 mm of which 790.0 mm is received soon south west monsoon and 91.0 mm in North East monsoon. The experiment was laid out in Randomized Block Design with three replications. The treatment was allocated to each replication randomly. The treatment comprised of three level of plant growth regulators GA_3 (control, 25, 50 and 75 ppm), NAA (control, 25, 50 and 75 ppm) and IBA (control, 25, 50 and 75 ppm. The seeds were sown with spacing row to row 45 cm and plant to plant 15 cm on dated 13-08-2019.

Result and Discussion

Effect of Foliar Application Of Plant Growth Regulators On Growth And Yield Of Okra

Plant height (cm)

The result on the plant height indicated that application of GA_3, NAA, IBA on okra had increased height as compare to control. In present investigation, results in respect of plant height, clearly revealed that plant growth regulators increased plant height at all stages of growth. (Table 1) Maximum plant height (42.01) at 45 DAS, (78.13) at 60 DAS, (87.26) at 75 DAS and (89.98) at 90 DAS was observed in the treatment (T_3) GA_3 75 ppm followed by the treatment (T_2) GA_3 50 ppm at 45, 60 and 75 days after sowing, and at 90 DAS treatment (T_9) IBA 75 ppm. At 45, 60 and 75 DAS treatment IBA 75 ppm (T_9), treatment (T_1) GA_3 25 ppm and at 90 DAS treatment (T_2) GA_3 50 ppm, treatment (T_8) IBA 50 ppm were next superior treatments in increasing plant height.

Table 1: Effect of plant growth regulators on plant height (cm).

Sr. No.	Treatments	Plant Height (cm)			
		45 DAS	60 DAS	75 DAS	90 DAS
T_1	GA_3 25 ppm	35.27	71.25	82.96	84.32
T_2	GA_3 50 ppm	39.23	74.06	84.29	86.16
T_3	GA_3 75 ppm	42.01	78.13	87.26	89.98
T_4	NAA 25 ppm	32.66	62.13	74.29	81.36
T_5	NAA 50 ppm	34.32	63.18	78.23	82.12
T_6	NAA 75 ppm	36.58	65.06	81.29	85.42
T_7	IBA 25 ppm	33.20	68.19	78.51	80.31
T_8	IBA 50 ppm	35.16	70.31	82.07	86.06
T_9	IBA 75 ppm	38.07	72.61	84.85	87.27
T_{10}	Control	31.12	52.05	63.18	73.13
	S.E. m ±	1.65	2.07	1.52	1.30
	C.D. at 5%	4..91	6.17	4.53	3.87

More plant height in GA_3 might have occurred due to cell elongation, increased cell wall plasticity which in turn would have increased intermodal length. The results are supported by the findings reported by various research workers. reported by Bhagure and Tambe (2011) [3], Rani *et al.* (2013) [10], Shahid *et al.* (2013) [12], Ravat and Makani (2015) [11].

Number of branches per plant

The data in respect of mean number of branches per plant as significantly influenced by different treatments is presented in table 2. The number of branches per plant were increased at all stages *i.e.* 45, 60, 75 and 90 DAS. Among 10 treatments, the higher number of branches at 45, 60, 75 and 90 DAS (2.81, 3.72, 3.92 and 4.10 respectively). The lowest number of branches per plant were recorded under control (T_{10}). The values for this character revealed that the treatment GA_3 75 ppm (T_3) at 90 DAS was recorded maximum number of branches (4.10).

Table 2: Effect of plant growth regulators on mean number of branches per plant

Sr. No.	Treatments	Number of branches plant^{-1}			
		45 DAS	60 DAS	75 DAS	90 DAS
T_1	GA_3 25 ppm	2.48	3.19	3.35	3.48
T_2	GA_3 50 ppm	2.61	3.51	3.62	3.79
T_3	GA_3 75 ppm	2.81	3.72	3.92	4.10
T_4	NAA 25 ppm	2.05	2.91	3.13	3.35
T_5	NAA 50 ppm	2.03	2.86	3.19	3.44
T_6	NAA 75 ppm	2.39	3.24	3.51	3.76
T_7	IBA 25 ppm	1.93	2.81	3.05	3.33
T_8	IBA 50 ppm	2.41	3.30	3.55	4.02
T_9	IBA 75 ppm	2.67	3.47	3.79	4.01
T_{10}	Control	1.43	2.03	2.12	2.28
	S.E. m ±	0.23	0.20	0.17	0.15
	C.D. at 5%	0.69	0.60	0.51	0.45

The results are supported by findings reported by various research workers. Bhagure and Tambe (2011) [3], Mehraj *et al.* (2015) [9].

Number of leaves per plant

The data on mean number of leaves per plant as influenced by different treatments is presented in table 3. The maximum number of leaves (23.13) was recorded under the treatment GA_3 75 ppm followed by GA_3 50 ppm (22.90 leaves), IBA 75 ppm (22.76 leaves), IBA 50 ppm (22.68 leaves), NAA 75 ppm (22.55 leaves). The minimum number of leaves (11.42) was recorded under control (T_{10}). The effect of GA_3 which increased the rate of cell division and cell elongation and ultimately increased the number of leaves in okra plants. The results are supported by the findings reported by various research workers. Bhagure and Tambe (2011) [3], Bello (2015) [2].

Table 3: Effect of plant growth regulators on mean number of leaves per plant

Sr. No.	Treatments	Number of leaves plant^{-1}			
		45 DAS	60 DAS	75 DAS	90 DAS
T_1	GA_3 25 ppm	11.72	16.25	21.05	21.48
T_2	GA_3 50 ppm	12.28	16.32	21.35	22.90
T_3	GA_3 75 ppm	12.21	16.51	22.00	23.13
T_4	NAA 25 ppm	11.40	15.51	19.65	21.16
T_5	NAA 50 ppm	11.54	16.18	19.80	21.37
T_6	NAA 75 ppm	11.78	16.26	21.08	22.55
T_7	IBA 25 ppm	11.56	15.86	19.76	21.33
T_8	IBA 50 ppm	11.69	16.26	21.12	22.68
T_9	IBA 75 ppm	11.89	16.33	21.22	22.76
T_{10}	Control	11.42	15.3	17.09	19.02
	S.E. m ±	0.20	0.16	0.26	0.22
	C.D. at 5%	0.61	0.48	0.78	0.66

Number of flowers per plant

Number of flowers per plant is an important yield contributing character and all the treatments of plant growth regulators at different concentration affected it significantly (Table 4). The treatment NAA 75 ppm (T_6) produced significantly more number of flowers per plant (6.5) and it was statistically at par with treatment NAA 50 ppm (T_5), treatment NAA 25 ppm (T_4), treatment GA_3 75 ppm (T_3), treatment GA_3 50 ppm (T_2), treatment GA_3 25 ppm (T_1), treatment IBA 75 ppm (T_9) respectively. The lower number of flower 3.26 per plant was recorded under control. similar study were reported by Surendra P *et al.* (2006) [14].

Table 4: Effect of plant growth regulators on mean number of flowers per plant

Sr. No.	Treatments	Number of flower plant^{-1}			
		45 DAS	60 DAS	75 DAS	90 DAS
T_1	GA_3 25 ppm	3.98	5.66	6.1	3.93
T_2	GA_3 50 ppm	4.2	5.73	6.06	4.3
T_3	GA_3 75 ppm	4.33	6.04	6.16	4.3
T_4	NAA 25 ppm	3.8	5.4	6.26	4.13
T_5	NAA 50 ppm	3.9	5.5	6.33	4.33
T_6	NAA 75 ppm	4.17	5.77	6.5	4.4
T_7	IBA 25 ppm	3.7	5.03	5.7	4.00
T_8	IBA 50 ppm	3.9	5.16	5.76	4.07
T_9	IBA 75 ppm	4.13	5.37	5.84	4.27
T_{10}	Control	3.3	4.36	4.7	3.26
	S.E. m ±	0.18	0.17	0.24	0.16
	C.D. at 5%	0.54	0.51	0.72	0.48

Days to 50% flowering [1]

The data on mean number of Days to 50% flowering as affected by various treatments is presented in table 5. Almost all the treatments had reduced the days to 50 percent flowering as compared to control. The data recorded on number of days required for 50 percent flowering were reduced in treatment NAA 75 ppm (T_6) was followed by NAA 50 ppm (T_5), NAA 25 ppm (T_4), GA_3 75 ppm (T_3), GA_3 50 ppm (T_2), GA_3 25 ppm (T_1), IBA 75 ppm (T_9), IBA 25 ppm (T_7) and IBA 50 ppm (T_8) respectively. All the concentration of GA_3, NAA and IBA were resulted in earlier production of 50 percent flowering significantly at earlier DAS as compared to treatment T_{10} (control).The results are supported by various research workers. Singh *et al.* (2012) [13].

Table 5: Effect of plant growth regulators on mean number of days to 50% flowering

Sr. No.	Treatments	Days after sowing
T_1	GA_3 25 ppm	46.94
T_2	GA_3 50 ppm	46.27
T_3	GA_3 75 ppm	44.00
T_4	NAA 25 ppm	42.16
T_5	NAA 50 ppm	42.00
T_6	NAA 75 ppm	41.00
T_7	IBA 25 ppm	47.27
T_8	IBA 50 ppm	47.98
T_9	IBA 75 ppm	47.00
T_{10}	Control	50.00
	S.E. m ±	0.38
	C.D. at 5%	1.14

Fresh fruit weight

The data on mean fresh fruit weight as affected by various treatments is presented in table 6. Treatment GA_3 50 ppm gave significantly superior result (14.04 g) than rest of treatment. T_{10} (control) recorded least fruit weight (10.29 g) in comparison with other treatment. The results are supported by findings reported by Mandal *et al.* (2012) [8].

Table 6: Effect of plant growth regulators on mean fresh fruit weight (gm)

Sr. No.	Treatments	Fresh fruit weight (gm)			
		45 DAS	60 DAS	75 DAS	90 DAS
T_1	GA_3 25 ppm	13.20	12.90	13.00	13.85
T_2	GA_3 50 ppm	13.28	12.93	13.03	14.04
T_3	GA_3 75 ppm	13.20	13.02	13.85	14.03
T_4	NAA 25 ppm	12.68	12.42	12.48	13.35
T_5	NAA 50 ppm	12.87	12.63	12.59	13.51
T_6	NAA 75 ppm	13.10	12.88	12.93	13.76
T_7	IBA 25 ppm	12.35	11.34	11.63	12.35
T_8	IBA 50 ppm	12.66	11.66	11.63	12.66
T_9	IBA 75 ppm	12.93	11.79	11.93	12.93
T_{10}	Control	12.00	10.29	11.41	11.97
	S.E. m ±	0.23	0.20	0.17	0.15
	C.D. at 5%	0.69	0.60	0.51	0.45

Number of fruits per plant

The data on number of fruits per plant as affected by various treatments is presented in table 7. All the treatments of plant growth regulators increased number of fruits per plant as compared to control (T_{10}). Treatment NAA 50 ppm (T_5) produced more number of fruits per plant (5.06) than rest of the treatments under study.

Table 7: Effect of plant growth regulators on mean number of fruits per plant

Sr. No.	Treatments	Number of fruits plant^{-1}			
		45 DAS	60 DAS	75 DAS	90 DAS
T_1	GA_3 25 ppm	3.46	4.46	4.8	3.43
T_2	GA_3 50 ppm	3.6	4.53	4.86	3.50
T_3	GA_3 75 ppm	3.86	4.80	4.73	3.53
T_4	NAA 25 ppm	3.33	4.36	4.93	3.46
T_5	NAA 50 ppm	3.46	4.80	5.06	3.53
T_6	NAA 75 ppm	3.60	4.93	4.86	3.53
T_7	IBA 25 ppm	3.33	4.60	4.80	3.20
T_8	IBA 50 ppm	3.4	4.60	4.73	3.40
T_9	IBA 75 ppm	3.53	4.80	4.80	3.46
T_{10}	Control	2.86	3.93	4.06	3.33
	S.E. m	0.16	0.18	0.16	0.18
	C.D. at 5%	0.48	0.53	0.50	0.55

Fruit yield per plant/ plot / hectare

The data on fruit yield as affected by various treatments is presented in table 8.

The fruit yield per plant/plot/hectare increased by all the treatments as compared to T_{10} (control). With incremental application of gibberellic acid, naphthalene acetic acid, indole-3-butyric acid, numbers of fruit were found increased. The highest fruit yield per plant/plot/hectare was found in treatment GA_3 75 ppm (T_3) significantly superior over treatment T_{10} (control) and followed by treatment GA_3 50 ppm (T_2).

The highest fruit yield per plant (223.80 g), per plot (11.63 kg) and per hectare (161.57 qt) was obtained in treatment GA_3 75 ppm (T_3). The lowest fruit yield per plant (161.92 g), per plot (8.41 kg) and hectare (116.85 qt) was produced by T_{10} (control).

These results are in conformation with the result reported by Kokare *et al.* (2006) [7], Chowdhary *et al.* (2014) [4].

Table 8: Effect of plant growth regulators on mean fruit yield per plant, mean fruit yield per plot and mean fruit yield per hectare.

Sr. No.	Treatments	Fruit yield plant^{-1} (g)	Fruit yield plot^{-1} (kg)	Fruit yield hectare^{-1} (qt)
T_1	GA_3 25 ppm	213.72	11.10	154.25
T_2	GA_3 50 ppm	219.84	11.42	158.7
T_3	GA_3 75 ppm	223.80	11.63	161.57
T_4	NAA 25 ppm	205.50	10.68	148.33
T_5	NAA 50 ppm	217.58	11.31	157.07
T_6	NAA 75 ppm	216.22	11.23	156.06
T_7	IBA 25 ppm	189.83	9.86	137.03
T_8	IBA 50 ppm	196.05	10.19	141.57
T_9	IBA 75 ppm	205.91	10.70	148.60
T_{10}	Control	161.92	8.41	116.85
	S.E. m	5.87	0.30	4.24
	C.D. at 5%	17.44	0.90	12.60

Conclusion

Result of present investigation revealed that, in general, growth regulators were effective in increasing growth and yield of okra.

Amongst various plant growth regulators T_3 (GA_3 75 ppm) recorded superior result in respect of growth.

However, plant growth regulator IBA 75 ppm (T_9) recorded second most superior result in respect of growth.

Maximum yield was recorded under treatment of plant growth regulator GA_3 75 ppm (T_3) while, control recorded minimum crop yield.

Nevertheless, to arrive at proper conclusion, few more trails are essential and it will be varies from field to field.

1. Treatment T_3 (GA_3 75 ppm) and T_9 (IBA 75 ppm) were found beneficial effect on growth of okra.
2. Maximum yield was recorded under the treatment of plant growth regulator GA_3 75 ppm

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